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A trajectory-based estimate of the tropospheric ozone column using the residual method

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[1] We estimate the tropospheric column ozone using a forward trajectory model to increase the horizontal resolution of the Aura Microwave Limb Sounder (MLS) derived stratospheric column ozone. Subtracting the MLS stratospheric column from Ozone Monitoring Instrument total column measurements gives the trajectory enhanced tropospheric ozone residual (TTOR). Because of different tropopause definitions, we validate the basic residual technique by computing the 200-hPa-to-surface column and comparing it to the same product from ozonesondes and Tropospheric Emission Spectrometer measurements. Comparisons show good agreement in the tropics and reasonable agreement at middle latitudes, but there is a persistent low bias in the TTOR that may be due to a slight high bias in MLS stratospheric column. With the improved stratospheric column resolution, we note a strong correlation of extratropical tropospheric ozone column anomalies with probable troposphere-stratosphere exchange events or folds. The folds can be identified by their colocation with strong horizontal tropopause gradients. TTOR anomalies due to folds may be mistaken for pollution events since folds often occur in the Atlantic and Pacific pollution corridors. We also compare the 200-hPa-to-surface column with Global Modeling Initiative chemical model estimates of the same quantity. While the tropical comparisons are good, we note that chemical model variations in 200-hPa-to-surface column at middle latitudes are much smaller than seen in the TTOR.

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1. Introduction

[2] The tropospheric column ozone residual method estimates the tropospheric column ozone by subtracting measurements of stratospheric ozone column from total column ozone. The tropospheric ozone column rarely exceeds 80 DU and thus is always a smaller component of the total ozone column (~250–500 DU). Total ozone column has been accurately measured by the Total Ozone Mapping Spectrometer instrument series starting in late 1978 and most recently the Dutch-Finnish Ozone Monitoring Instrument (OMI) [*Levelt et al.*, 2006] on Aura. Although tropospheric ozone can be estimated directly using UV instruments [e.g., *Liu et al.*, 2006], we focus on the residual technique because, in theory, it can produce a more precise tropospheric column. The key to producing the tropospheric column is an accurate estimation of the larger stratospheric ozone column. Various instruments have been used to derive the stratospheric column including Stratospheric Aerosol and Gas Experiment II [*Fishman and Larsen*, 1987; *Fishman et al.*, 1990], Upper Atmosphere Research Satellite (UARS) Microwave Limb Sounder (MLS) [*Chandra et al.*, 2003] and Aura's Earth Observing System MLS [*Ziemke et al.*, 2006, hereinafter referred to as Z06]. Up until the launch of Aura and ENVISAT, near simultaneous stratospheric column and total column ozone amounts were not available. A brief review of tropospheric ozone residual techniques is given in Z06 and is not repeated here.

[3] The Aura MLS instrument [*Waters et al.*, 2006] can be used to estimate the stratospheric column as in Z06. One advantage of the Aura MLS over the previous UARS MLS instrument is that Aura MLS was designed to retrieve ozone in the lower stratosphere and upper troposphere (UTLS). The second advantage is that because Aura is in a Sun-synchronous orbit, Aura MLS instrument can produce near global maps of stratospheric column on a daily basis. The OMI and MLS instruments onboard the Aura spacecraft have been providing global measurements of total column ozone and stratospheric column soon after the launch of Aura on 15 July 2004 [*Schoeberl et al.*, 2006]. This has enabled near global estimates of the tropospheric column on almost a day-to-day basis from late September 2004 to present.

[4] In Z06, Aura MLS stratospheric column and OMI total column ozone data were used to produce a monthly mean and daily tropospheric ozone residual. However, with only ~14.6 orbits a day, the MLS ascending node (daytime) measurements of stratospheric column provide only a low horizontal resolution mapped product (~24.7° longitude by ~2° latitude). The interpolation of MLS data onto the OMI grid to generate the residual, implicitly forces smaller-scale variability seen in the OMI total column ozone to be part of the tropospheric column. This assumption probably does not strongly affect the computation of the monthly mean residual because the smaller-scale variability will average out in a month. Indeed, Z06 showed that monthly mean sonde profiles were consistent with residual estimates from ozonesondes. However, the Z06 method does not produce a reasonable extratropical product as judged by sonde comparison (shown below). We hypothesize that the main problem is that the approach used by Z06 has to be modified to account for stratospheric column spatial variability.

[5] In this study, we use forward trajectory calculations to boost the horizontal resolution of the stratospheric column, and this allows us to generate an improved daily tropospheric ozone residual. In the next section, we describe the data and method. We validate our results with daily ozonesondes. We also compare the data with Tropospheric Emission Spectrometer (TES) [*Beer*, 2006] direct estimates of the ozone column. We show some examples of tropospheric enhancements near tropopause folds: midlatitude synoptic-scale features often associated with jumps in the tropopause height along jets and cutoff low pressure systems. These jumps are often colocated with changes in column ozone and water vapor and can be diagnosed from satellite data [*Wimmers and Moody*, 2004]. The fold enhancements in ozone are clearly present in the observations. Finally we show how our estimates of the tropospheric column compare with NASA Global Modeling Initiative (GMI) estimates of the column (see Z06).

7. Summary

[50] Forward trajectories are used to increase the spatial resolution of the stratospheric ozone column in order to produce a higher-resolution tropospheric column ozone using the residual method. We use the OMI-Total Ozone Mapping Spectrometer algorithm for the total column and MLS V1.5 for the stratosphere. We refer to this product as the Trajectory Total Ozone Residual (TTOR). We compare the 200-hPa-to-surface column (200TSC) TTOR against the 200TSC from sondes and TES measurements. Using the 200TSC removes issues associated with different tropopause definitions. Comparisons with sondes and TES show good agreement in the tropics and reasonable agreement at middle latitudes. TTOR is an improvement over the Z06 daily product as is shown by comparison to sondes. Nonetheless there is a persistent low bias in the TTOR which appears to be due to high bias in the MLS (V1.5) lower stratospheric mixing ratio. This low bias led Z06 to add 2.3 DU of ozone to their product which shows up in our comparisons with their product. We also note that there is much more variability in the midlatitude TTOR than ozonesondes show. This is probably due to the fact that MLS, with its 3–4 km weighting function and lower precision in the lower stratosphere, cannot resolve the steep ozone gradient at the midlatitude tropopause.

[51] There is a strong correlation of extratropical tropospheric column anomalies with probable troposphere-stratosphere folds that are identified by large tropopause height gradients. Tropospheric ozone residual anomalies due to folds may be mistaken for pollution events since they often occur in the Atlantic and Pacific pollution corridors. We also compare the 200TSC with GMI estimates of the tropospheric column. While the tropical comparisons are good, we note that GMI variations in 200TSC at middle latitudes are much smaller than those estimated using TTOR thus GMI is somewhat closer to the ozonesondes analysis; however, more extensive comparisons between GMI and ozonesondes remain to be done.